Blended and online learning: A comparative study of virtual microscopy in Higher Education

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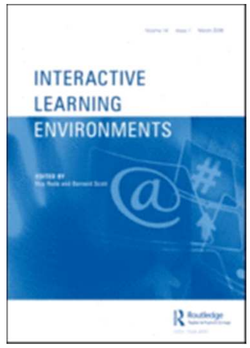

Blended and online learning: A comparative study of virtual microscopy in higher education

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Abstract

Virtual learning Environments (VLEs) are becoming commonplace in Higher Education. Amongst the latest VLE developments is the design and use of Virtual Microscopes (VMs) that allow for viewing and manipulation of online images by multiple students. Although students are found to be generally satisfied with the use of VMs, it is yet not known what teaching and learning conditions better support their use and lead to enhanced learning outcomes. The aim of this paper is to compare the usage patterns and perceptions of two different cohorts of undergraduate students that made use of the VM in blended and online only learning conditions respectively, and draw conclusions about the pedagogy that better supports teaching and learning with VMs. Data collected from a survey with 139 students and 11 semi-structured interviews revealed that blended learning better caters for students' engagement and satisfaction due to the systematic use of the VM in course design, its complementary use with a physical microscope, and the ongoing provision of tutors' support and guidance. Equally good perceived learning gains were reported by both blended and online only students. Implications for the design of learning environments around virtual microscopy are discussed.

Keywords: virtual microscopes; VLEs; pedagogy; online learning; blended learning; higher education.

Introduction

Virtual Learning Environments (VLEs) are commonly used in Higher Education (e.g., Barajas & Owen, 2000), with most lecture, practical, tutorial and other materials being hosted on platforms such as Moodle and Blackboard for students to download and revise at their ease. Of crucial importance in the use of VLEs is ensuring that students are engaged and learn from learning materials whilst not limiting their experience due to constraints in infrastructure or compounding common disadvantages associated with any web-based simulation (Byrne, Heavey, & Byrne, 2010).

There are several challenges associated with the implementation of VLEs including student engagement (Dale & Lane, 2007), how to enhance feedback and assessment and ensure consistency across platforms and learning environments (Allen & Bentley, 2012), and how to mitigate against infrastructure problems (Fry *et al*, 2015). The implementation of blended learning methods, that is a combination of online learning and face-to-face instruction (Mayadas & Picciano, 2007) has enhanced student learning, engagement and performance (Becerra et al, 2015), enabling the educator to more readily address some of the challenges noted above whilst providing an environment that allows for deeper learning and consolidation.

Teaching with Virtual Microscopes

Amongst the mechanisms that can support learning in VLEs is the use of Virtual Microscopes (VMs). The widespread development of VMs for biology, in particular histology, was driven in part by issues related to the use of human tissue (Dee, 2009; Heidger et al., 2002), the potential for telepathology and education (samples viewing by many students) (Weinstein et al., 2009; Gatumu et al., 2014). One of the main pedagogical advantages of a VM, as illustrated by its uses in the literature cited above, is the simultaneous viewing and manipulation of the same slide by multiple end users, an activity that could not be achieved with a physical microscope. VMs are very common in biology and health sciences (Becerra et al., 2015), yet less common in earth and materials science (e.g., Tetley & Daczko 2014). This may partly be due to the fact that using microscopy to study thin sections of rocks requires multiple lighting conditions and rotation to view pleochroism, birefringence colours and extinction.

VMs have been implemented across a range of subject areas where large teaching laboratories with microscopes were formerly used to teach observation, identification, and classification skills. The use of VMs has expanded rapidly to be applied in the teaching of for example, biology (e.g., Childers & Jones, 2015), histology (e.g., Gatumu et al., 2014), dentistry (e.g., McCready et al., 2013), haematology (e.g. Thomas et al., 2014), and veterinary science (e.g., Brown et al. 2016).

These studies have mainly consisted of surveys asking students to compare their impressions of physical versus virtual microscopes (e.g., Kumar et al. 2004) and sometimes of relatively simple student surveys with often only positive questions (e.g., Sağol et al., 2015). Most studies indicate consistently high levels of satisfaction and enthusiasm among students and staff for VMs (e.g., Brown et al., 2016) with assessments indicating that students do equally well when using either traditional or virtual techniques. Of particular note is that the best results so far come from combining virtual and physical microscopy (Sancho et al., 2006; Becerra et al., 2015; Gatuma et al., 2014; Brown et al., 2016), with the flipped classroom concept suggesting that such access to materials outside of the traditional classroom can enhance learning in class (Tune et al., 2013; Fielding et al., 2014).

There are relatively few studies of student perceptions of their own learning or potential improvements in pedagogy (teaching, learning, assessment) with the notable exception of Childers and Jones (2015), who examined the effects of ownership and virtual presence during a remote experiment, and a recent partnership between five UK universities (http://www.geolab.ie/virtual-microscope/) with the aim to develop VM-related teaching and learning resources. A dearth of evidence is observed around evaluating the effectiveness of adopted pedagogy around VMs. The pedagogical conditions, such as learning and assessment activities and interactions amongst students and between students and the teacher, remain underexplored. It is yet not known how the VM is integrated in learning activities in blended and online only conditions is perceived by students, whether and why this may be engaging and useful and, foremost, whether it is perceived as having a positive impact on student performance. Without a good understanding of the underlying pedagogy and simply allowing students access to digitized materials is unlikely to promote learning and lead to enhanced performance (McBride & Prayson, 2008). Such insights could inform the design and development of online and blended learning courses and related material.

Aims and research questions

Through a mixed-method study, this paper aims to enhance existing pedagogy (teaching, learning, and assessment) around the use of virtual optical microscopy in Higher Education by comparing students' perceptions and usage patterns of VMs in blended and online only teaching and learning conditions. Specific questions are:

1. How do students' VM usage patterns compare in blended and online only conditions?
2. How do students' perceptions about learning from using the VM compare in blended and online only conditions?
3. How do students' perceptions about the VM pedagogical integration into their courses compare in blended and online only conditions?
4. Drawing from 1, 2 and 3, what pedagogical conditions better support students' engagement and learning with VMs?

Online and blended learning

Several studies compared the learning effectiveness of online and blended learning environments, with evidence mainly in support of the latter. For example, through a randomised control trial, Al-Qahtani and Higgins (2012) identified significant differences between blended, online and traditional learning conditions, with students in blended learning conditions demonstrating better achievements. No differences were observed between online and traditional teaching conditions. In another experimental study by Demirer and Sahin (2013), no differences were identified between the blended and the online only groups in achievement, yet significant differences were observed in transfer of learning for the blended conditions. Students who attended both online and face-to-face sessions transferred knowledge to their project more successfully than students attending online sessions only.

In the next paragraphs, we describe the blended and online only settings within which the VM has been used in the current study. These settings are in a campus-based and a distance learning universities respectively. The UK VM is the VM used in both settings (see Figure 1)

→ Insert Figure 1 about here

Virtual microscope in blended learning conditions

In the campus-based university (CBU), the UKVM is used in an earth science course, following a two-week routine: outline of materials and minerals for study in tutor-led practical classes with time focused on specific microscope functions for mineral identification. At the end of each two-week laboratory block, students were set online multiple-choice question tests that were linked to specific sections of the UKVM (see Figure 2).

→ Insert Figure 2 about here

Virtual microscope in online only learning conditions

The use of the UKVM at the distance learning university (DLU) was integrated into Earth science and Biology courses at several points via hyperlinks in the online text. Virtual microscopy is introduced during the early weeks of each course and students are asked to use it. Microscopy then forms part of activities that ask students to illustrate specific VM features such as measuring the size of some parasites, calibrating and using the measuring tool or the grid, comparing images, and discussing findings with their teachers and fellow students.

→Insert Figure 3 about here

Methodology

Methods of data collection

Data were collected from two higher education institutions, a campus-based university (CBU) and a distance learning university (DLU) in the UK, that make use of the VM in blended and online only conditions respectively. A mixed-methods approach consisting of a survey with 139 undergraduate students and 11 semi-structured interviews was used for data collection. The survey consisted of a set of mainly 5-point Likert type questions, that were conceptually grouped in the following categories: (a) usage patterns e.g., I visited often the VM webpage during the module, (b) VM features most often used e.g., magnification, measurements options, (c) occasions when the VM is used e.g., review before an assignment, (d) perceived learning gains e.g., using the VM improved my observation skills, (e) Satisfaction with the VM integration into the course and preferences for teaching activities that make use of the VM e.g., group work (multiple choice), (f) previous experience of using a VM (yes/no), (g) previous experience of using a physical microscope (yes/no), (h) problems encountered when using the VM (yes/no, open-ended i.e., detail the problems encountered), (i) intention to use the VM in the future (yes/no, open-ended i.e., justify why you plan to use it or not). Cronbach's alpha values ranged between 0.72 and 0.81 and were considered as acceptable (Tavakol & Dennick, 2011).

→Insert Table 1 here

The survey was administered to students attending a year 1 Earth's Materials course at the CBU (CBU; N=66), and a year 2 Earth Science (N=37) and a year 3 Biology course (N=36) at the DLU. Convenience sampling was used for course selection. Given the blended nature of teaching and learning at the CBU, a paper version of the survey was allocated to students in person with 80% response rate. In terms of the DLU, an online invitation was sent to 386 students attending the two online courses. A 18.9% of students provided a response. The low response rate of students in online surveys as opposed to paper-based ones is not uncommon (e.g., Nulty, 2008), with evidence showing similar to this study's response rates for students studying online (Buckley, 2014). In both settings, the sample was self-selected with the obvious (self-selecting) biases (Torgerson & Torgerson, 2008). Participation was voluntary and consent was gained prior to the completion of the survey. Participants were debriefed about the aims of the study, their data being anonymised and used for research purposes only, and their right to withdraw at anytime and have their data destroyed. All survey participants entered a draw with the prize of a £20 Amazon voucher.

Interviews were semi-structured and aimed to triangulate and unpack insights from survey data. Interviewees were self-selected and identified through the pool of students who completed the survey. An interview protocol was used during the interview with questions such as: How did you access the VM? How was the VM introduced to you? Was it necessary to follow the VM to understand the content under study or was it supplementary? Each interview lasted approximately 20 minutes. A £10 Amazon voucher was offered to each interviewee as incentive to participation. Interviews were conducted online by an independent researcher (Author 3) to minimise potential biases and enhance the validity of the data collected.

Participants

The survey was completed by two different cohorts of students: students from one campus-based, face-to-face university (CBU), who used the VM in blended learning conditions, and students from a distance learning university (DLU), who used the VM in online only learning conditions. The two cohorts of students presented substantial differences in terms of demographic characteristics and these were considered in the follow-up analysis. In terms of gender, almost half of the CBU students (48.5%) were male with 37.9% being female (13.6% missing data). In contrast, a great majority of 69.9% were female at the DLU and 30.1% only were male. In terms of age, almost all CBU students were 21 years old or younger (95.5%). On the contrary, a 56.2% of the DLU students were 40 years old or older and 37% between 25-39 years old. Aligning with the age discrepancy, 42.4% of the CBU students reported to be studying only, while a 43.8% of the DLU students were in full time occupation.

In terms of previous education achieved, a 57.6% of the CBU cohort finished high school, 9.1% college and 21.2% a bachelor's degree. Most of the DLU students either had A levels or equivalent qualification (34.2%) or a higher education qualification (31.5%). In both cohorts, students were not new to university studies; 75.8% of the CBU cohort and 95.9% of the DLU cohort were continuing students, that is, they had previously attended university courses. A percentage of 72.7% of the CBU cohort had used a conventional microscope in the past either at school or at the university. A considerably lower percentage of DLU students (47.9%) reported they had used a conventional microscope in the past at school, previous study or work.

Interviews were conducted with 11 students (n_female=6; n_male=5; Age: n=5, 19-23 years old; n=6, 28-49 years old) from the two aforementioned universities. Overall, five students were studying an Earth material course, four students an earth science and biology courses, and two students used the VM in various instances.

Data Analysis

Survey

Mean comparisons between the two cohorts of students were made in the four subscales (see Table 1) and adjusted after controlling for covariates, in particular, age, gender, and previous experiences of using a VM and a physical microscope. Analysis of Covariance (ANCOVA) was performed to adjust for covariates.

Is there a difference in usage patterns between blended and online only students?

Statistically significant differences were observed in usage patterns between the two cohorts of students, with CBU students having more positive perceptions about VM usage as compared to DLU students. A follow-up ANCOVA revealed no statistically significant differences between the blended and online only conditions (F (1, 108) =.476, *p*=.492, NS) (see Table 3). After entering covariates one by one in the model, it was revealed that age is the covariate that adjusted mean differences in blended and online only groups (F (1, 111= .452, *p*=.503, eta2=.004) and not gender (F (1,113) =1.92, *p*=.010, eta2=.06), previous VM (F (1, 121)= 1.88, *p*=.010, eta2=.053) and physical microscope experience (F (1, 122)=6.53, *p*=.012, eta2=.051) (see Table 4).

→Insert Table 2 here

→ Insert Table 3 here

Is there a difference in the frequency of using the VM features between blended and online only students?

ANCOVA analysis revealed statistically significant differences between the two cohorts of students, after controlling for age, gender, and previous experiences of using a VM and a physical microscope (see Table 5), suggesting that DLU students make more frequent use of VM features. This is not a surprising insight given that DLU students have access only to a virtual and not a physical microscope, thus VM is their only means to examine and understand samples.

→Insert Table 4 here

→Insert Table 5 here

Is there a difference in occasions when the VM is used between blended and online only students?

ANCOVA analysis controlling for age, gender, and previous experiences of using a VM and a physical microscope, revealed no statistically significant differences between the two cohorts of students after controlling for covariates.

→ Insert Table 6 here.

→ Insert Table 7 here.

Is there a difference in perceived learning gains between blended and online only students?

ANCOVA analysis revealed that, after controlling for age, gender and previous experiences of using a VM and a physical microscope, no statistically significant differences between the two groups of students pertained (see Tables 9, 10). Entering covariates one by one in the model, it was identified that age was the covariate explaining differences between groups suggesting that perceptions of learning from using the VM is a function of age and not of teaching condition (blended, online only).

→ Insert Table 8 here.

→ Insert Table 9 here.

Is there a difference in satisfaction from VM integration in the course between blended and online only students?

After controlling for covariates, blended students reported more satisfaction from how the VM was used in their studies (see Table 11, 12). In terms of students' *preferences for teaching activities,* the great majority of students in both cohorts disliked a potential use of the VM in group work (CBU: 24%; DLU: 19%) and having connections to social media (CBU: 23%, DLU: 7%). Using the VM as part of an investigation (or assessed investigation) was endorsed by approximately half of the students in each cohort (CBU:57%, DLU: 42%). Online tutorials and other tutor-led activities were more favoured by CBU students (65%; 53%) as compared to DLU students (30%; 34%).

→ Insert Table 10 here.

→ Insert Table 11 here.

Is there a difference in problems encountered when using the VM and intention to use the VM in the future between blended and online only students?

Problems encountered when using the VM: A percentage of 21.5% of the CBU cohort reported some problems when using the VM such as difficulty in identifying minerals, technical issues such as browser compatibility and loading issues. A percentage of 7.3% of the DLU students reported problems with the VM including, for example, technical issues and effectiveness of VM features such as rotation and zoom in. These data indicate that most students in both blended and online only learning conditions did not encounter difficulties when using the VM.

Intention to use the VM in the future: Almost all of the CBU students (98.5%) would be interested in using the VM in the future for a variety of reasons such as study away from the lab, revision, use of real samples, easy to use, support of content knowledge. A percentage of 72.9% of the DLU students reported an interest in using the VM in the future due to reasons such as easy calibration, good quality of images, practical hands-on experience, study material becomes more engaging, access anywhere and anytime. Students who were not interested in using the VM in the future explained their intention with (a) specific VM features including, bad image quality, difficulty in colour differentiation, loading on portable devices, and (b) the pedagogy behind the use of the VM, including a lack of guidance when recognising samples, no added value to written material, comparable to static images, lack of explanations as to why to use the VM, no systematic inclusion in assessment and feedback provision.

Interview Analysis

Thematic analysis (Braun & Clarke, 2006) was used to analyse the data collected from 11 interviews with students. The analysis followed an inductive, data-driven approach of identifying themes. Initial codes were generated through nVivo, with some content falling within more than one codes. Themes were identified by Author 3 after analysing a small number of scripts and verified or modified where necessary by Author 1 to ensure inter-rater reliability. The inter-rater percentage agreement, which equals to 80%, was calculated by dividing the number of times both researchers agreed by the total number of times coding was possible (Boyiatzis, 1998). The two researchers resolved the mismatches by spitting, merging and creating new more descriptive themes. The final emerging themes are highlighted below.

Prior experiences with microscopes. Almost all the participating students had previous experiences of using microscopes at school or studying with physical microscopes in previous university courses. Only one student had never used a microscope before: *'Well I didn't before I started the course, but now working in a school I have done, but I didn't have previous experience.' (Car, 42, Female, DLU)*

VM features used. Although some students made use of all the VM features, others had preferences for features such as the descriptions and history of rocks, viewing the slides in different lighting (PPL and XPL), rotating the slides, viewing the interference colours, zooming, focusing and measuring. As one interviewee explains:

> *'I would read the descriptions which were really helpful in learning about the different minerals present in the rock, as well as a little history of the rock. Then I clicked on view microscope, usually we were told to go to different rotations, but I usually just looked at the mineral as a whole, using the PPL and XPL buttons, before going to a rotation and doing the same again." (Cal, 20, Female, CBU)*

VM duration & frequency of use. Frequency of use depended on the activities and assessments students had to complete, their free time, and the purpose for using the VM. Some students were using it 3-4 times a week, others once a week for completing all of their tasks, or more often if they were close to examinations. The duration of use ranged between 5 minutes to 2 hours a day and amongst the factors influencing interaction was the nature of learning activities, the level of familiarity with the VM, and the speed of the computer used: *'I would probably say I would stay on there for about an hour to 2 hours – but that's the nature of my course so – it's not to do with the fact that the VM is quite slow to navigate." (Top, 19, Male, CBU)*

Existing pedagogy. On-campus students referred to VM as a tool for doing quizzes, assessment, homework and looking at additional material, and analyzing sections on bigger screens. DLU students referred to the VM as a means to practise observation and identification of sections: *'We had an assessment and there was, I think, 3 or 4 different links to the VM for different rocks and then we had to look at them and answer questions regarding them' (Mar, 19, Male, CBU)*

> *"[We were using it] to actually identify minerals within rock compounds and such. We were practising and enhancing the art of observation and how we can identify different features of different minerals." (Var, 32, Female, DLU)*

The VM was the basic means of viewing and understanding images for DLU students while this was complementary to a physical microscope for campus-based students:

> *"There was talk at the start of that practical and we went back to the practical after that and I think it was making note of the fact the samples we were using were also present on virtual microscope, so it was like if you can't finish them here you can look at home later on as a kind of complimentary thing." (Pum, 23, Male, CPU)*

Tutors were those introducing the VM and allowed time for students to play with it, provided samples, gave examples on how to use it, and equivalent minerals in physical microscope to relate the real and virtual slides: *'So it was introduced via a lecturer and we were given time to basically go and play with it and then, as I say, our assessment we were given samples that we had to go and look at and answer questions on it as well!" (Dolomite, 36, Male, CBU)*

The DLU students were introduced to the VM either through an introductory activity or video tutorials before they move to actual use. There were no live introductions from a tutor and no feedback given to students' understanding, often inhibiting learning:

> *'There was a little tutorial [...], it just showed you how to use the different features on there. It was a bit boring there is nothing like getting your hands on an actual microscope and having somebody there to talk you through it, [...] and if you think you have understood something and you haven't you have no-body left to back that up because you are sat at home on your own with a computer screen." (Var, 32, Female, DLU)*

Quizzes and written assessments were the means for evaluating VM understanding. In some cases, students reported no assessment around the VM: *"In [the biology course] I wouldn't say the assignments really tested you on that."* (Carbonatite, 42, Female, DLU).

Accessing VM and usability. Participating students were accessing the VM in different ways, including hyperlinks in the activities, searching for the VM on the internet or a combination of the two. For the DLU students, the hyperlink to the VM could also be found in the course study resources: *'Yes, sometimes there was [a link to activities] and then other times I would just Google VM and it would come up and go in that way." (Hy, 21, Female, CBU).* Regarding the usability of the VM, none of the students had problems accessing it. Most students found it very simple and easy to use, with clear descriptions and guidelines on where and what to look at. The VM was perceived to be straightforward and easier to use compared to a physical microscope:

> *'I thought it was a very simplistic way, it was very like there was not much challenge to understand. It was simply click a few buttons and you were brought to like a menu option and then put your show on as well, it was not like a physical microscope where you look through thin sections and you were completely unsure where to look.'* (Pum, 21, Male, CBU)

Despite being perceived as easy to use, students faced some challenges in relation to navigation, not having clear image and going through many steps to find samples: "*I think one of the issues I found sometimes – and this is probably to do with servers was that when you were rotating the images [...] when that was happening sometimes the image would disappear at certain rotations*" (Top, 19, Male, CBU).

Perceived usefulness. The VM was perceived as useful due to its flexibility of being used at one's own time and place. For the DLU students, the VM was the only way to access a microscope. All students perceived the VM as a tool for training and preparing for using a physical one. In addition, the VM gave access to samples not included in the library collection of the university. In relation to knowledge, it helped students draw previous knowledge together, understand concepts by looking at illustrations of specific things, view interpretations when they were confused, refresh their existing knowledge, and develop their identification skills: *'I wouldn't have said it [VM] was necessary [for studying the material], because we also had labs* *and textbooks and other exercises which helped our understanding, but the VM definitely helped draw it all together.' (Calcite, 20, Female, CBU)*

Physical microscope Vs VM. A universal preference for using a physical microscope than a virtual microscope was observed. Amongst the reasons explaining this preference was the engagement with the process of preparing the thin sections and choosing the rotation point, the flexibility of twisting and turning the slides, viewing the whole slide, and better image quality. Yet, students recognised the merits of using a VM in particular when there is no access to a physical microscope: *"I think they both have their merits! Obviously if you could have access to a real microscope at home it would be handy but with that said, with the VM comes notes and things that can help you as well, so it has some strong points going for it!" (Dol, 36, Male, CBU).*

Suggestions for improvements. Suggestions were made as to how to enhance the pedagogy behind the VM including, expanding the rock library collection with more samples and providing more teaching material relevant to VM. The DLU students in particular commented on introducing the VM in a more interactive way and in comparison to the physical microscope, add more feedback functions, and support from tutors: *'What I did like about that as opposed to the virtual one is that while we were using it we had tutors present with us [...], being able to ask a question and being able to get an answer straightaway.'* (Jas, 28, Female, DLU).

Suggestions were also made about improving the VM technology, including having bigger images, especially during rotation, improving the rotation as images disappeared at certain rotations, navigational issues, tablet functionality, and addition of social features such as communication tools for interaction with students and scientists working with VM samples:

'Sometimes I wished it were bigger [images] when you were actually into the rotation side of things!'(Dol, 36, Male, CBU).

Discussion

The aim of this paper was to compare the perceptions and experiences of two different cohorts of students about virtual optical microscopy and identify which pedagogical conditions (blended or online only) better support learning and engagement. Data were collected from a campus-based university adopting a blended learning approach to using the VM and an online distance learning university adopting an online learning approach.

In terms of *RQ1 Usage patterns and general perceptions***,** students from both institutions visited often the VM webpage, perceived it as being easy to access through web links or searching the web, and useful for both the courses under study and their studies in general. Interview data suggested that frequency and duration of VM use were depended on the type of activities and assessment students were required to complete. Although campus-based students were found to enjoy more the VM than online students, after controlling for age, gender, and previous experiences of using microscopes, no differences between the two cohorts of students pertained. Age was the covariate explaining differences between groups, suggesting that perceptions of enjoyment from learning with VMs depend on the age of students. These findings align well with existing studies reporting that the VM is endorsed with enjoyment and enthusiasm by students (e.g., Thomas et al., 2014).

In addition, and after controlling for covariates, VM features such as magnification, lighting, and zoom, were used more frequently in online settings. Interview data explained this tendency further; the VM was the only means to examine and understand samples in online settings whereas this was complementary to a physical microscope in blended learning conditions. In terms of when students made use of the VM, both cohorts of students reported moderate use for reviewing before exams or preparing an assignment. Interview data revealed that using the VM was perceived by both cohorts of students as preparation for using the physical microscope and giving access to samples not accessible through other means.

In terms of *RQ2 Perceived learning gains*, students perceived the VM as mostly enhancing their observation and identification skills and their understanding of what is taught in the course. They reported improvements in learning how to determine the magnification of materials, confidence in using the VM, while they recognised the importance of the VM for accomplishing the course aims. Statistical comparisons between the two cohorts of students revealed that age was explaining observed differences in perceived improvements in observation skills between cohorts suggesting that using the VM in blended (along with a physical microscope) and online learning conditions can equally cater for students' learning needs (e.g., Brown et al., 2016). Interviews revealed a universal preference from both campus and online students to use a physical than a virtual microscope due to for example, engaging with the process of preparing thin sections. These preferences were based on previous experiences of using a physical microscope.

In terms of *RQ3 Perceptions about VM pedagogical integration*, quantitative analysis revealed that CBU students liked the pedagogical integration surrounding the use of the VM in the course more than online students after controlling for covariates, indicating that demographic characteristics (age and gender) and previous experiences with microscopes, do not relate to observed differences. Students in blended learning conditions were more satisfied with how the VM was integrated in their course as opposed to online students. Interview data illuminated further this discrepancy; campus students used the VM for a variety of learning activities including quizzes, assessment, homework, looking at additional material, and analysing sections on bigger screens, while online students used it as a means to practise observation and identification of sections. For the former group, the VM was complementary to a physical microscope, while for the latter the basic means of viewing and understanding images. In addition, the role of the teacher or tutor was found to be crucial in the learning experience. While campus students explained that the VM was introduced by their tutors though different activities, the online group stressed the need for a tutor to complement online VM activities, tutorials and videos, and provide feedback to their understanding. This finding aligns well with existing studies reporting on the importance of the tutor as discussion facilitator in online learning environments than in blended learning ones (Hung & Chou, 2015).

In terms of *RQ4 Pedagogical conditions better supporting engagement and learning*, findings from this study indicate that blended learning conditions better support engagement with the VM, yet not self-perceived learning gains, mainly due to the high frequency of using the VM in a course, its complementary use with a physical microscope, and the role of tutors in supporting and guiding students' learning. This is largely due to the VM being fully integrated to the course and not simply an adjunct. In particular, students were found to be more satisfied with how the VM was integrated in blended learning conditions than students in online conditions. Yet, they enjoyed equally its use.

In terms of perceived learning gains, confirming existing studies (Overbaugh & Nickel, 2011), both cohorts of students recognised that using the VM was beneficial for their learning as it enhanced their observation and identification skills and understanding of what is taught in the course. Students learnt how to determine the magnification of materials, were confident in using the VM and perceived it as important for accomplishing the course aims. No perceived differences in learning gains from using the VM in their studies were observed.

In relation to students' preferences for teaching activities that make use of the VM, half of the students in each cohort expressed an interest in using the VM as part of investigations. Also, the majority of both cohorts expressed a dislike in using the VM as part of group work or connected to social media suggesting that social interactions or peer work might not be the best approach to supporting learning using the VM in blended and online settings. These findings align well with Overbaugh and Nickel (2011) study about academic community in university courses. While students in both blended and online conditions were found to be satisfied and with high degrees of perceived learning gains, they presented neutral connectedness scores (e.g., connectedness with classmates, preference for collaboration, valuing collaboration) indicating that course community-building is less likely to contribute or affect learning. Drawing from interview data, existing pedagogy could be enhanced by expanding the library collection with more samples, providing more teaching material relevant to VM, introducing the VM in a more interactive way, adding feedback functions, and support from tutors.

Conclusions

This study examined the usage, experiences and perceived learning impact of the VM on undergraduate students' learning and engagement in blended and online only settings. Evidence suggest that students in blended learning conditions are more satisfied with how the VM is used, mainly due to the supportive role of teachers, the complementary use along with a physical microscope and its frequent use throughout the course duration. Yet, blended learning conditions did not cater for better learning outcomes as perceived by students, but equally good with online only settings.

Student retention in Higher Education has been debated and explored by many authors with several differing factors having impact on an institution's own statistics. Students who feel relaxed and able to talk to their teachers are more likely to seek help and remedy any perceived problems *before* they consider dropping out (Thomas, 2002). Reviewing completion rates at the campus university, it was observed that over a period of three years and after blended learning was adopted, non-completion at year 1 courses in Geology dropped from 11% to 3%. Furthermore, once students entered year 2, their familiarity with blended learning led to an easier transition into other courses that already utilised these approaches. As a result, non-completion remained lower in Level 2 and year-on-year grades and attainment saw a significant improvement compared to previous years in which blended methods were absent.

Findings from this study suggest that the use of VM in online only conditions currently may not support student engagement and satisfaction with learning as well as it could as it is mostly used as an add-on to current materials. Alexander (2001) suggested that a VLE can be more effective when embedding simulations or problem exercises than simply using it as a data repository or for simple provision of information. Such an approach would allow students and tutors to engage more readily with the VM and its functionality. Of particular note is how the VM has been used at the CBU that has allowed for an extension of the classroom and the development of a semiotic domain that the students share and engage with. Available VM materials on their own would not have been sufficient to serve the needs of the course. The VLE added some crucial materials that were not necessarily available in class. Consequently, the blended nature of the VLE was not achieved by integrating the VM into an existing course; it was more about making best use of the materials and facilities both in the classroom and on the VM to *develop* a blended course. To produce a successful blended product, it is necessary to thoroughly and iteratively review the existing classroom-taught content in the light of the advantages and extra facility that the VM allows.

This study showcased that student perceptions of the VM have been largely positive, with a unique insight to blended learning conditions for the implementation of integrated VLEs. With such integration in place, it is more likely that student attainment and retention will improve. Of significant importance for future consideration is the design and robust evaluation of virtual microscopy within particular courses to determine whether and why specific pedagogies outperform existing approaches and which of them lead to a significant effect on students' performance and retention. It is also essential to consider for students' demographic characteristics such as age and how these may affect their engagement and use of VLEs.

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References

Alexander, S. 2001. E-learning developments and experiences. *Education & Training*, 43, 240–248.

Al-Qahtani, A.A.Y. and Higgins, S.E. 2013. Effects of traditional, blended and e-learning on students' achievement in higher education. *Journal of Computer Assisted Learning*. 29, 3 (2013), 220–234. DOI:https://doi.org/10.1111/j.1365-2729.2012.00490.x.

Barajas, M. & Owen, M., 2000. Implementing virtual learning environments: Looking for holistic approach. *Educational Technology & Society*, *3*(3), pp.39-53.

Becerra, D., Grob, M., Rodriguez, A., Barker, M.J., Consiglieri, L., Ferri, G., Sabag, N., 2015. Academic Achievement and Perception of Two Teaching Methods in Histology: Light Microscopy and Digital Systems. *International Journal of Morphology 33*, 811 – 816.

Braun, V., & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Brown, P.J., Fews, D., Bell, N.J., 2016. Teaching Veterinary Histopathology: A Comparison of Microscopy and Digital Slides. *Journal of Veterinary Medical Education* 43,13-20.

Boyatzis, R. 1998. *Transforming qualitative information: Thematic analysis and code development.* California: Sage.

Buckley, A. (2014). UK Engagement Survey 2014: The second Pilot Year. York: Higher Education Academy.

Byrne, J., Heavey, C. & Byrne, P.J., 2010. A review of Web-based simulation and supporting tools. *Simulation Modelling Practice and Theory, 18*, 253-276.

Childers, G & Jones, M.G., 2015. Students as Virtual Scientists: An exploration of students' and teachers' perceived realness of a remote electron microscopy investigation, International *Journal of Science Education*, 37(15), 2433-2452.

Dale, C. & Lane, A.M., 2007. A Wolf in Sheep's Clothing? An analysis of student engagement with virtual learning environments. *Journal of Hospitality, Leisure, Sport and Tourism Education*, Vol 6, No. 2, p100-108.

Del Blanco, A., Torrente, J., Moreno-Ger, P. and Fernández-Manjón, B., 2011. Enhancing adaptive learning and assessment in virtual learning environments with educational games. *IJDET-Intelligent Learning Systems and Advancements in Computer-Aided Instruction: Emerging Studies*, pp.144-163.

Dee, F.R., 2009. Virtual microscopy in pathology education. *Human Pathology 40*, pp.1112 – 1121.

Demirer, V. and Sahin, I. 2013. Effect of blended learning environment on transfer of learning: An experimental study. *Journal of Computer Assisted Learning*. 29, 6 (2013), 518–529. DOI:https://doi.org/10.1111/jcal.12009.

Fielding, D., Maldonado, F., Murgu, S., 2014. Achieving competency in bronchoscopy: Challenges and opportunities. *Respirology*,19(4): 472–482.

Fry, H., Ketteridge, S. & Marshall, S., 2015. A Handbook for Teaching and Learning in Higher Education. *London: Rutledge. (Fourth edition).*

Gatumu, M.K., MacMillan, F.M., Langton, P.D., Headley, P.M., Harris, J.R., 2014. Evaluation of Usage of Virtual Microscopy for the Study of Histology in the Medical, Dental, and Veterinary Undergraduate Programs of a UK University. *Anatomical Sciences Education 7*, 389 – 398.

Haywood, J., Anderson, C., Coyle, H., Day, K., Haywood, D., & Macleod, H., 2000. Learning technology in Scottish higher education—a survey. *Alt-J*, 8(2), 5–17.

Heidger, P.M., Dee, F., Consoer, D., Leaven, T., Duncan, J., Kreiter, C., 2002. Integrated approach to teaching and testing in histology with real and virtual imaging. *Anatomical Record 269*, 107 – 112.

Hodson, P., Saunders, D., & Stubbs, G., 2002. Computer-assisted assessment: Staff viewpoints on its introduction within a new university. *Innovations in Education and Teaching International,* 39(2), 145–152.

Hung, M. & Chou, C. 2015. Students' perceptions of instructors' roles in blended and online learning environments: A comparative study. *Computers & Education*. 81, 315–325. DOI:https://doi.org/10.1016/j.compedu.2014.10.022.

Kelley, S. 2016. The Virtual Microscope for Earth Science. Quarterly Enhancement Report Series. *The Open University, UK*.

Klein, N., 1999. No logo: Taking aim at the brand bullies. *New York: Picador*.

Mayadas, A. F. & Picciano, A. G. (2007) Blended learning and localness: The means and the end. Journal of Asynchronous Learning Networks, 11, 3–7.

McCready, Z.R., Jham, B.C., 2013. Dental Students' Perceptions of the Use of Digital Microscopy as Part of an Oral Pathology Curriculum. *Journal of Dental Education, 77*, 1624-1628.

McBride, J.M., Prayson, R.A., 2008. Development of a synergistic case-based microanatomy curriculum. Anatomical Sciences Education, 1:102–105.

Nulty, D.D. (2008). The adequacy of response rates to online and paper surveys: What can be done? *Assessment and Evaluation in Higher Education*. 33, 3, 301–314. DOI: https://doi.org/10.1080/02602930701293231.

Overbaugh, R.C. & Nickel, C.E. 2011. A comparison of student satisfaction and value of academic community between blended and online sections of a university-level educational foundations course. Internet and Higher Education. 14, 3, 164–174. DOI:https://doi.org/10.1016/j.iheduc.2010.12.001.

Sağol, Ö., Yőrűkoğlu, K., Lebe, B., Durak, M.G., Ulukuş, Ç., Tuna, B., Musal, B., Canda, T., and Özer, E. 2015. Transition to Virtual Microscopy in Medical Undergraduate Pathology Education: First Experience of Turkey in Dokuz Eylül University Hospital. Turkish Journal of Pathology, 31(3), 175-180.

Parizotto-Ribiero, R., Hammond, N., Mansano, J. and Cziulik, C., 2004. Aesthetics and perceived usability of VLEs: preliminary results. *Proceedings of Human Computer Interaction*, pp.217-221.

QAA., 2014. Higher Education Review: Themes for 2015-2016. Retrieved March 18, from http://www.qaa.ac.uk/publications/information-and-guidance/publication?PubID=2859#.VyI5SbRRdFJ

Sancho. P, R Corral. R, Rivas. T, González. M. J, Chordi. A, and Tejedor. C. 2006. A Blended Learning Experience for Teaching Microbiology. *American Journal of Pharmaceutical Education*, 70 (5), Article 120.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. http://doi.org/10.5116/ijme.4dfb.8dfd

Tetley, M.G., Daczko, N.R., 2014. Virtual Petrographic Microscope: A multi-platform education and research software tool to analyse rock thin-sections. *Australian Journal of Earth Sciences 61*, 631 – 637.

Thomas, A., Ng, W., Hill, S., Rizvi, H., Radia, D., 2014. A Virtual Microscopy Learning Platform – a High Quality, Innovative and Interactive Tool for Training Haematologists of the Future: A UK Pilot Study. *Blood, 124* (21), 4846.

Thomas, L., 2002. Student retention in higher education: The role of institutional habitus, *Journal of Education Policy, 17:4*, 423-442.

Torgerson, D. J., & Torgerson, C. 2008. *Designing randomised trials in health, education and the social sciences: an introduction*. London: Palgrave Macmillan.

Tuchman, G., 2009. Wannabe U: Inside the corporate university. *Chicago: University of Chicago Press.*

Tune J, Sturek M, Basile, D., 2013. Flipped classroom model improves graduate student performance in cardiovascular, respiratory, and renal physiology. *Adv Physiol Educ 37(4),* 316–320.

Weinstein, R.S., Graham, A.R., Richter, L.C., Barker, G.P., Krupinski, E.A., Lopez, A.M., Erps, K.A., Bhattacharyya, A.K., Yagi, Y., Gilbertson, J.R., 2009. Overview of telepathology, virtual microscopy, and whole slide imaging: Prospects for the future. *Human Pathology 40*, 1057 – 1069.

Whalley, P., Kelley, S.P. and Tindle, A. 2010. The Role of the Virtual Microscope in Distance Learning. Open Learning: *The Journal of Open and Distance Learning 26*, 127 – 134.

Figure 1. The UK Virtual Microscope

A: Front-end user view of VM webpage for a rock thin section (Olivine Gabbro).

B: Thin section under 'View Microscope' tab showing both plain polarised (PPL) and cross polarised light (XPL).

C: Fully rotatable PPL and XPL views of thin sections from numbered portions in B.

Figure 2. Example questions tied to specific tasks and features of the UK VM in blended learning.

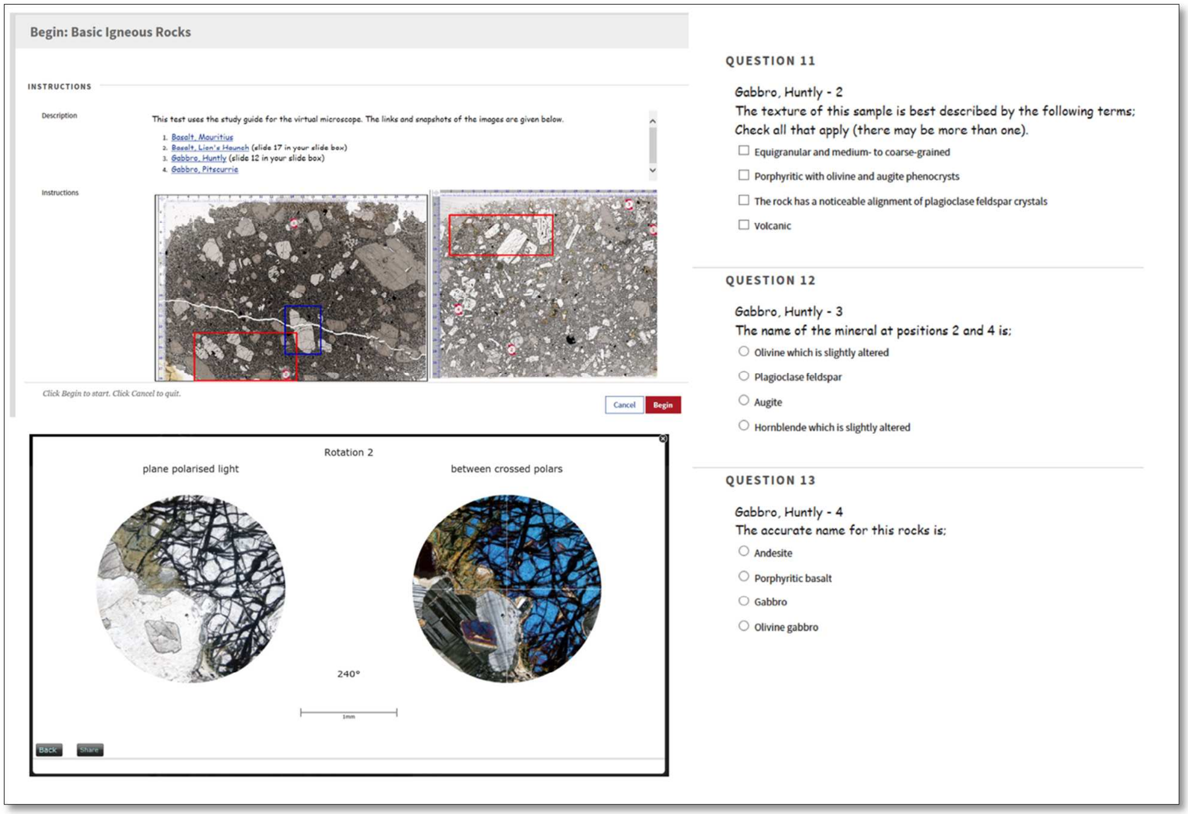
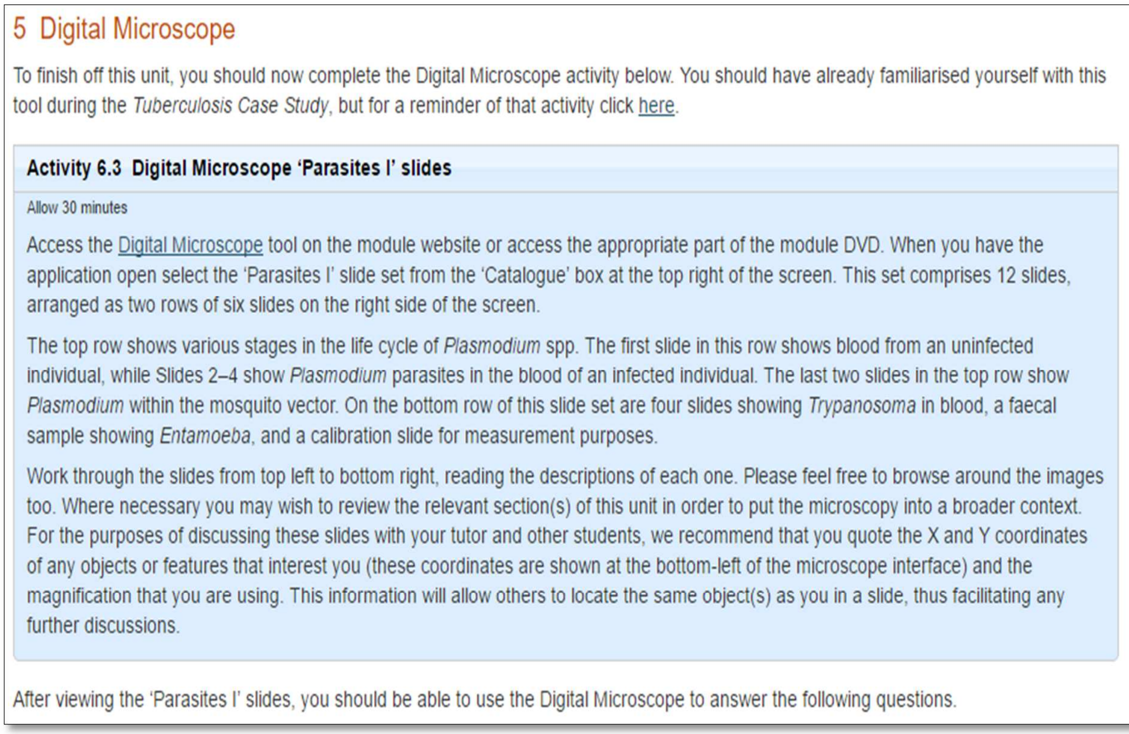


Figure 3. An example activity of how the UKVM is used in a biology course in online learning conditions.


5 Digital Microscope

To finish off this unit, you should now complete the Digital Microscope activity below. You should have already familiarised yourself with this tool during the *Tuberculosis Case Study*, but for a reminder of that activity click here.

Activity 6.3 Digital Microscope 'Parasites I' slides

Allow 30 minutes

Access the Digital Microscope tool on the module website or access the appropriate part of the module DVD. When you have the application open select the 'Parasites I' slide set from the 'Catalogue' box at the top right of the screen. This set comprises 12 slides, arranged as two rows of six slides on the right side of the screen.

The top row shows various stages in the life cycle of *Plasmodium* spp. The first slide in this row shows blood from an uninfected individual, while Slides 2–4 show *Plasmodium* parasites in the blood of an infected individual. The last two slides in the top row show *Plasmodium* within the mosquito vector. On the bottom row of this slide set are four slides showing *Trypanosoma* in blood, a faecal sample showing *Entamoeba*, and a calibration slide for measurement purposes.

Work through the slides from top left to bottom right, reading the descriptions of each one. Please feel free to browse around the images too. Where necessary you may wish to review the relevant section(s) of this unit in order to put the microscopy into a broader context. For the purposes of discussing these slides with your tutor and other students, we recommend that you quote the X and Y coordinates of any objects or features that interest you (these coordinates are shown at the bottom-left of the microscope interface) and the magnification that you are using. This information will allow others to locate the same object(s) as you in a slide, thus facilitating any further discussions.

After viewing the 'Parasites I' slides, you should be able to use the Digital Microscope to answer the following questions.

Table 1

Reliability analysis of 5-point Likert-type subscales included in the survey

Description of scale	N of items	Alpha coefficient
Usage patterns	9	a=.76
VM features often used	6	a=.72
Occasions when the VM is used	7	a=.82
Perceived learning gains	5	a=.81

Table 2. Analysis of covariance for usage patterns as a function of blended or online only conditions and covariates age, gender, previous experience of VM and physical microscope.

Variable		*df*	*MS*	*F*	*p*	*eta2*
Covariate	Age	1	.471	1.713	.193	.016
Covariate	Gender	1	.062	.226	.635	.002
Covariate	Previous VM experience	1	.067	.242	.624	.002
Covariate	Previous physical microscope experience	1	.160	.583	.447	.005
Factor	Blended/Online only groups	1	.131	.476	.492	.004
Error	Error	108	.275			

Table 3. Adjusted and unadjusted group means for usage patterns

		Unadjusted		*Adjusted*	
	N	*M*	*SD*	*M*	*SE*
Blended	55	3.61	.27	3.53	.10
Online only	59	3.33	.67	3.41	.09

Table 4. Analysis of covariance for VM features as a function of blended or online only conditions and covariates age, gender, previous experience of VM and physical microscope.

Variable		*df*	*MS*	*F*	*p*	*eta2*
Covariate	Age	1	.175	.320	.573	.003
Covariate	Gender	1	1.78	3.26	.074	.030
Covariate	Previous VM experience	1	.082	.151	.699	.001
Covariate	Previous physical microscope experience	1	.034	.063	.802	.001
Factor	Blended/Online only groups	1	3.31	6.08	.015*	.055
Error	Error	104	.546			

**p<.05*

Table 5. Adjusted and unadjusted group means for VM features

		Unadjusted		Adjusted	
	N	*M*	*SD*	*M*	*SE*
Blended	52	3.48	.62	3.49	.143
Online only	58	4.09	.83	4.07	.132

Table 6. Analysis of covariance for occasions when the VM is used as a function of blended or online only conditions and covariates age, gender, previous experience of VM and physical microscope.

Variable		*df*	*MS*	*F*	*p*	*eta2*
Covariate	Age	1	1.61	2.52	.117	.037
Covariate	Gender	1	.627	.98	.326	.015
Covariate	Previous VM experience	1	.054	.084	.773	.001
Covariate	Previous physical microscope experience	1	.079	.123	.727	.002
Factor	Blended/Online only groups	1	.197	.308	.581	.005
Error	Error	66	.546			

**p<.05*

Table 7. Adjusted and unadjusted group means for occasions when the VM is used

		Unadjusted		Adjusted	

	N	*M*	*SD*	*M*	*SE*
Blended	52	3.24	.69	3.10	.140
Online only	58	2.59	.99	2.92	.253

Table 8. Analysis of covariance for perceived learning as a function of blended or online only conditions and covariates age, gender, previous experience of VM and physical microscope.

Variable		*df*	*MS*	*F*	*p*	*eta2*
Covariate	Age	1	.595	1.79	.184	.017
Covariate	Gender	1	.243	.729	.395	.007
Covariate	Previous VM experience	1	.037	.111	.739	.001
Covariate	Previous physical microscope experience	1	.040	.119	.730	.001
Factor	Blended/Online only groups	1	.011	.032	.858	.000
Error	Error	102	.102			

**p<.05*

Table 9. Adjusted and unadjusted group means for perceived learning

	Unadjusted		*Adjusted*	

	N	M	SD	M	SE
Blended	55	3.58	.51	3.47	.11
Online only	53	3.49	.63	3.51	.11

Table 10. Analysis of covariance for VM integration in courses as a function of blended or online only conditions and covariates age, gender, previous experience of VM and physical microscope.

Variable		*df*	*MS*	*F*	*p*	*eta2*
Covariate	Age	1	.065	.075	.784	.001
Covariate	Gender	1	.285	.330	.567	.003
Covariate	Previous VM experience	1	2.14	2.48	.12	.024
Covariate	Previous physical microscope experience	1	.114	.133	.716	.001
Factor	Blended/Online only groups	1	5.94	6.89	.010*	.063
Error	Error	102	.862			

**p<.05*

Table 11. Adjusted and unadjusted group means for VM integration in courses

		Unadjusted		*Adjusted*	
	N	*M*	*SD*	*M*	*SE*

Blended	55	4.18	.61	4.16	.17
Online only	53	3.36	1.16	3.37	.18